The symmetrical maze: An automated closed-field test series for rats

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An automated "intelligence" test for rats is described. Supporting data indicate that this maze-problem series is sensitive to hypothyroidism-induced learning deficit and sex differences. Comparisons between this new problem set and the Rabinovitch-Rosvold (1951) closed-field tests are presented with respect to difficulty, internal consistency, and test-retest reliability.

Closed-field maze tests of the Hebb-Williams (1946) and Rabinovitch-Rosvold (1951) type are simple and inexpensive to construct, have demonstrated reliability (Rabinovitch & Rosvold, 1951), and can be used fruitfully in species comparisons (e.g., Livesey, 1966). Moreover, they have a justified claim to "validity by definition" as tests of animal intelligence on the argument that they provide a fairly extensive sampling of behavior over the course of several different learning problems, even though there are probably important kinds of learning capacity they do not tap. In addition, the Rabinovitch-Rosvold tests in particular have revealed early-experience effects and behavioral deficits in "retarded" animals with a degree of regularity that is impressive when measured against the apparent insensitivity of many other learning tasks in the areas of developmental psychobiology and comparative psychology.

We have devised a closed-field maze apparatus for rats that is automated except for the scoring of errors. This apparatus, called the symmetrical maze, has shown a degree of sensitivity to behavioral deficit that appears to be comparable to that of the Rabinovitch-Rosvold tests and above that of several other learning tasks (Davenport, in press). In addition, it offers some advantages over the manual closed-field apparatuses in terms of convenience, accuracy of recording, consistency of external stimulation from trial to trial, reduction of E influences, and applicability to species comparison.

DESCRIPTION

The symmetrical maze is similar to the older apparatuses in its general form (see Fig. 1), the main differences being that motorized doors separate the endboxes from the field, and that the endboxes are equipped with photocells and automatic pellet dispensers. Each endbox functions as both a startbox and a goalbox, and the S runs in opposite directions on alternate trials (from A to B on odd-numbered, from B to A on even-numbered, trials). Normally, only symmetrical maze patterns (barriers placed in the field) are used, so that S faces the same sequence of turns going in either direction within a given problem.

In testing, the S is placed in Endbox A at the start of the session and is not further handled until reaching criterion on the problem. E effects are further reduced by enclosing the apparatus in a soundproof room. With the aid of closed-circuit television, errors are scored manually, as with the older apparatuses, but with somewhat greater accuracy because of the direct overhead view provided and the additional visual aid of overlay lines on the surface of the television monitor screen to define error zones. Trial times are recorded automatically on a printing counter.

The symmetrical maze patterns we have used are diagrammed in Fig. 2. The first 4 problems (P-1 through P-4) are practice problems; the remaining 12 problems (T-1 through T-12) constitute the main test series. Deliberate similarities exist between some of these patterns and those of Rabinovitch and Rosvold (1951, p. 124), but, in general, the range of difficulty of the present test series is greater than in the older closed-field series. The order of administration of the problems is as given in Fig. 2 and was designed to minimize positive transfer from a given problem to an immediately subsequent problem.

The apparatus is constructed of wooden side walls and barriers (painted flat black), a clear Plexiglas top, unpainted expanded aluminum flooring, and a stainless-steel drop pan (also flat black to reduce glare from the lights). The walls and barriers are 9.5 cm high, and the apparatus floor is 49.5 cm above the floor of the room. Two standard double-tube fluorescent fixtures are suspended 30.5 cm above the apparatus top.

The feeders (Davis) dispense 45-mg Noyes pellets into recessed foodcups

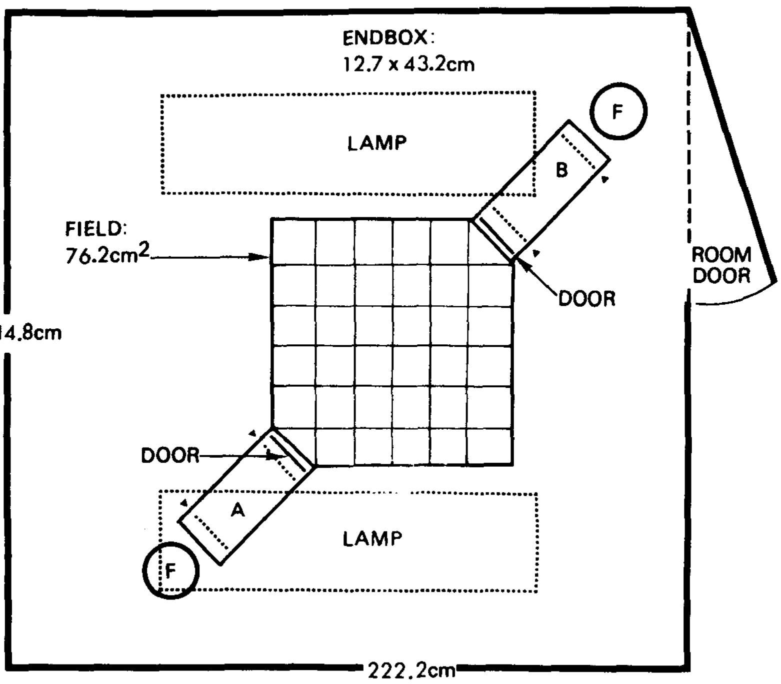

Fig. 1. Diagram of the apparatus in relation to the testing room. A and B are identical endboxes, adjacent to feeders (F). The triangles indicate photocell positions. Barriers (not shown) are placed in relation to the grid lines of the field.

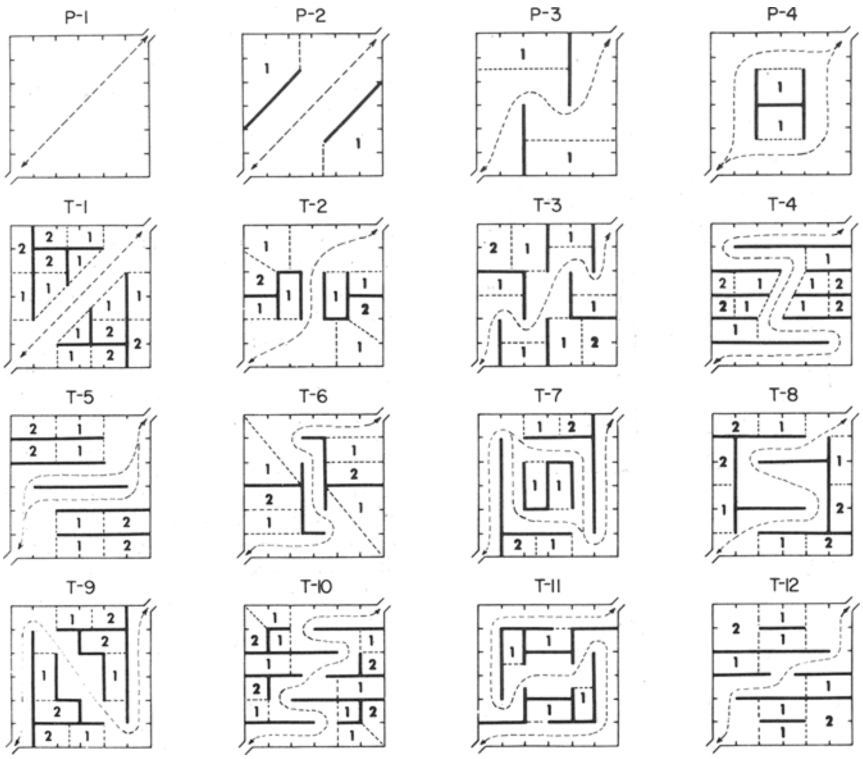

Fig. 2. The maze patterns used in the practice (P-1 through P-4) and test problems (T-1 through T-12) of the standard symmetrical series. Error zones are indicated by the numbers and dotted lines.

mounted at floor level on unpainted aluminum endplates of the endboxes. The clear Plexiglas doors at the endbox entryways are guillotine-type, energized by relay-controlled Hurst Type PC DA 60-rpm synchronous motors with clutches.

Programming is adequately handled by conventional operant conditioning modules. Circuitry is arranged so that a trial begins with the opening of both doors, deactivation of the photocells in the "start" endbox, and initiation of trial-time measurement. S is released into the field to find the opposite endbox and is free to retrace into the starting area. When S interrupts the second photobeam (near the foodcup) of the "goal" endbox, the trial-time measurement stops, both doors close, and reinforcement is delivered. (The other photocell in each endbox is used to sense the direction in which a trial is proceeding.) After a variable intertrial interval (no illumination change) averaging 15 sec, the next trial proceeds in the opposite direction.

STANDARD TESTING PROCEDURES

In most of our work with the apparatus, we have maintained a standard testing procedure in order to accumulate normative and correlational data for clearly defined groups of rats. The Ss are maintained at 85% of free-feeding weight and run on 18 to 23 h of food deprivation. The only pretraining prior to the practice problems is magazine training, and this is given only to naive animals that have had no exposure to automatic pellet dispensers. Two Ss at a time (one in each endbox) are magazine-trained in two sessions (endbox positions reversed in the second session) consisting of 60 pellets each, using a variable-interval 30-sec schedule of pellet presentations.

The practice and test problems are administered at the rate of one problem per day, with reward constant at two pellets on all trials. The practice problems are administered in set lengths of 12 trials each. In Problems T-1 through T-12, the Ss are run for a minimum of 12 trials and until they attain a criterion of 4 errorless trials in 5 consecutive trials or receive a maximum of 48 trials without reaching criterion.

Errors are scored according to the rules employed by Rabinovitch and Rosvold (1951, p. 125), except that crossing of an error line is judged in terms of the S's shoulders instead of its front feet because of the overhead view. Entrances by S into error zones marked "1" and "2" (see Fig. 2) are scored as one error for each zone entry (the "2" designation should be interpreted as cumulative), but entry or reentry of a "1" zone from a "2" zone is not scored as an additional (third) error, since this is unavoidable in moving from a "2" zone to the correct path. Retracing into a starting endbox, which occurs only rarely after the practice problems, is not scored as an error, nor is an incomplete entry into a "goal" endbox in which only the first of the two photobeams is interrupted. Crossings into error zones of the field after such an incomplete goalbox entry are scored as errors in the normal fashion.

Some investigators (e.g., Livesey, 1966) have distinguished between "visual" and "nonvisual" problems of the older closed-field tests on the basis of whether error zones are arranged so that an animal can avoid making errors in a given problem by seeing each cul-de-sac in its entirety without crossing an error line or whether the problem contains error zones (e.g., L-shaped culs), which can be viewed completely only after an error line has been crossed. In terms of this distinction, six of the symmetrical maze problems (T-1, T-4, T-5, T-6, T-7, and T-8) would be classed as visual and the remaining six as nonvisual. Of the latter six, however, three (T-3, T-11, and T-12) present somewhat ambiguous cases (see Fig. 2).

SUPPORTING DATA

Summary of Experience

We have tested 126 rats in the apparatus, of which 49 (all Holtzman albino rats) were subjected to chronic administration of tricyanoaminopropene (TCAP), thiouracil, desiccated thyroid, or a combination of TCAP and thyroid extract in early developmental stages. Since physical and behavioral abnormalities resulted from the early drug conditions, these Ss must be distinguished from 59 normal Holtzman rats we have tested and from an additional group of 18 female descendants of the Tryon (1940) "maze-bright" and "maze-dull" strains.

Only seven (four drug-treated, one maze-dull, and two normal) rats had to be dropped because of failure to respond during magazine training or practice problems. Excluding the remaining 17 Tryon rats (which did not receive the standard order and number of test problems), 87 of the remaining 102 rats reached criterion within the 48-trial maximum on all 12 test problems, and in the total of 1,244 tests, there were only 20 failures (12 by drug-treated, 8 by normal rats) to reach criterion. Thus, the test problems were generally within a normal

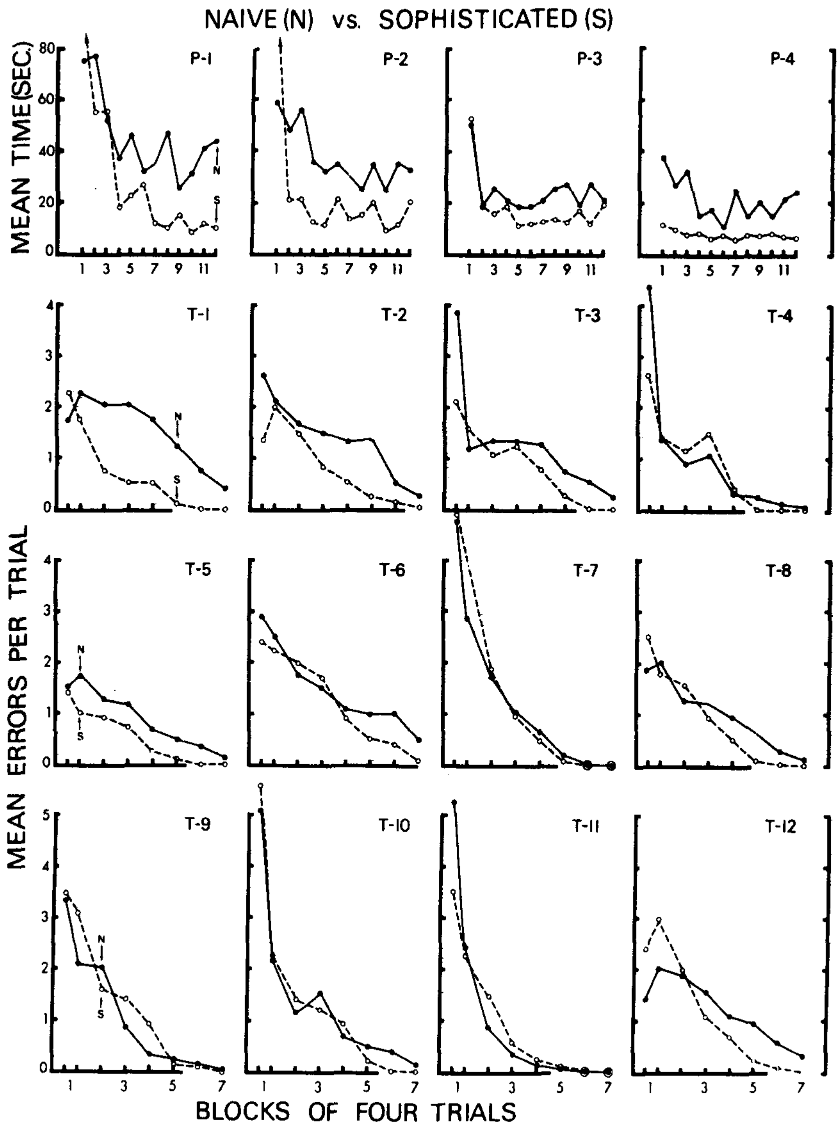

Fig. 3. Mean trial times on individual trials of the practice problems (top row) and mean errors per trial on the first 28 trials of the test problems (bottom three rows) by 30 naive-purchased (N) and 10 sophisticated-lab-reared (S) male rats.

rat's learning capacity, and the procedure of requiring S to shuttle in opposite directions on alternate trials was clearly a workable one.

No important difference in error scores was observed when odd-numbered trials (A-to-B direction) were compared with even-numbered (B-to-A) trials. Except for a small proportion of the animals which ran more slowly in one direction than in the other on practice problems, the Ss behaved in highly similar fashion in the A-to-B and B-to-A directions throughout the symmetrical problem series.

Normal Performance by Holtzman Rats

Three types of normal Holtzman rats have been tested in the apparatus: (1) sophisticated adult control Ss in our long-term hypothyroidism studies which were reared in the laboratory and received much handling and several learning tasks in other apparatuses (see Davenport, in press) before their symmetrical maze tests, (2) naive adult control Ss which were lab-reared and handled frequently in twice-weekly weighings between weaning and testing but had no exposure to other apparatuses, and (3) naive male rats purchased from the Holtzman Co. as adults which were immediately placed on deprivation and tested after minimal handling. These we refer to as sophisticated-lab-reared (S), naive-lab-reared (NL), and naive-purchased (N) groups, respectively. Means and standard deviations of errors-to-criterion scores on each of the 12 problems are provided for these groups in Table 1.

Figure 3 presents a comparison of 10 Group S and 30 Group N rats with respect to trial times on the 4 practice problems and mean errors per trial on the 12 test problems. Since individual rats received varying numbers of trials on the test problems and often received fewer than the 28 trials per problem shown in Fig. 3, the error curves were constructed on the assumption that no additional errors would have been made by a rat if it had been given more trials after reaching criterion. For each 4-trial block after the 12-trial minimum, the errors made by Ss still running in that block were simply totaled and averaged. In the first block, test-problem performance on Trial 1 was plotted separately from that on Trials 2 through 4 in the figure. The group comparisons in Table 1 and Fig. 3 were restricted to male rats because of the sex differences noted below.

The top panels of Fig. 3 show considerably slower running on the practice problems by the naive Ss, as we would expect, but the difference in trial times between the N and S groups declined over the practice problems and the first few test problems; little difference between

Table 1
Means and Standard Deviations of Error Scores by Three Groups of Normal Male Holtzman Rats

	Sophisticated (N = 10)		Naive Lab-Reared (N = 10)		Naive Purchased (N = 30)	
Problem	Mean	SD	Mean	SD	Mean	SD
T-1	15.1	10.7	18.9	10.2	42.5	22.5
T-2	20.3	8.5	24.0	8.7	35.7	16.0
T-3	19.6	9.1	15.3	8.0	30.2	12.8
T-4	16.6	6.0	16.4	3.1	19.0	5.6
T-5	13.0	5.4	17.4	8.3	24.1	12.8
T-6	31.3	11.6	25.3	8.1	42.2	20.3
T-7	31.4	9.6	21.2	6.2	27.0	14.8
T-8	20.9	8.1	28.3	10.7	27.5	13.3
T-9	28.6	11.8	18.7	5.6	19.3	7.5
T-10	25.9	8.6	20.1	11.4	28.7	11.8
T-11	20.2	6.8	14.9	4.3	17.0	4.8
T-12	27.5	8.3	30.4	20.8	34.8	14.9
Total (1-12)	270.4	25.9	250.9	30.6	350.5	76.9

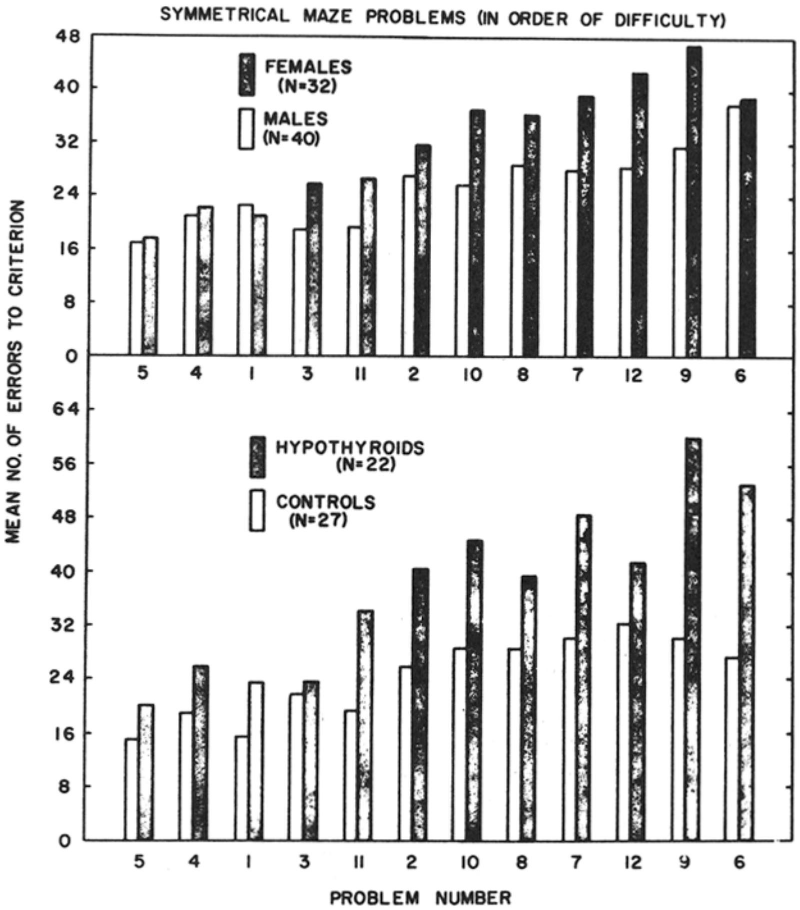

Fig. 4. Sex differences (upper graph) and hypothyroid-control differences (lower graph) on each of the 12 symmetrical test problems.

the groups was found in the last eight problems. The 10 Group NL males displayed trial times similar to those of Group N on Problem P-1 but reduced their times to the level of Group S by Problem P-4 and showed no difference thereafter.

Analysis of variance of the errors-to-criterion scores in all three normal groups revealed significant main effects of groups ($F = 8.61$, $df = 2/47$, $p < .001$) and problems ($F = 7.18$, $df = 11/517$, $p < .001$) and a significant Groups by Problems interaction ($F = 2.97$, $df = 22/517$, $p < .001$). Group N made significantly ($p < .01$, two-tailed LSD tests) more errors than did Group S on Problems T-1, T-2, T-3, T-5, and T-6.

The superiority of Group S was apparently not the result of their previous experience in other formal learning tasks, however, since the 10 Group NL males performed about as well as the Group S males on 10 of the 12 test problems (see Table 1) and somewhat better ($p < .05$) than Group S on Problems T-7 and T-9. (The superiority of Group NL over Group N was significant beyond the .01 level on T-1, T-2, T-3, and T-6.) It is possible, then, that extensive handling prior to exposure to the apparatus may be sufficient to bring error scores of naive rats down to the level of sophisticated Ss, even on the early test problems. In any event, the investigator must be wary of differences in prior handling or other early-experience factors in attempting to define normal performance in this apparatus. The evident sensitivity of the symmetrical maze problems to such factors parallels Rabinovitch and Rosvold's (1951) finding of fewer errors by an "enriched environment" group of rats.

We are accumulating more data for naive Holtzman rats as our use of the apparatus continues, in the hope that stable norms can be established for various researches involving the assessment of learning deficit or facilitation. Since there were only minor differences among the three groups of normal rats on the last six problems, the Table 1 data for these problems may be taken as first approximations of how normal, well adapted, male Holtzman rats in general perform on the latter half of the symmetrical maze test series. As later sections indicate, this is the portion of the test series that has disclosed the clearest differences between normal males and other groups of rats.

Figure 3 reveals large differences among the problems in overall difficulty level and in rate of error reduction. On some problems (e.g., T-7 and T-11), the initial error rate was very high but decreased to zero within 20 trials, while in some other problems (e.g., T-2 and T-6), a lower initial rate was followed by perseverative errors which continued beyond Trial 30. Since most of the Rabinovitch and Rosvold problems may be solved within 10 to 15 trials (by Holtzman rats, we have found, as well as by the hooded rats used by those authors), it is clear that the average difficulty level of our problems is well above theirs.

Sex Differences

Male rats have performed consistently better than female rats in terms of total errors over the 12 symmetrical test problems. A problem-by-problem comparison of 40 male and 32 female Holtzman rats is presented in the upper panel of Fig. 4, in which problems are arranged in order of difficulty as defined by errors for all 72 rats. Data from 45 drug-treated rats in our hypothyroidism studies are included in this comparison, but very similar sex differences were found when only the normal control rats' data were used. The Sex by Problem interaction indicated in Fig. 4 was statistically significant ($F = 2.89$, $df = 11/770$, $p < .01$). Subsequent Fisher LSD tests showed significantly ($p < .05$, two-tailed) more errors by the female rats on seven of the problems (T-3 and T-7 through T-12).

The sex difference here paralleled some unpublished data from our laboratory showing superiority of male rats in the Rabinovitch-Rosvold tests. In one experiment, the difference between 10 male and 13 female experienced Holtzman rats in total errors over the 12 Rabinovitch-Rosvold problems (means were 176.6 and 316.2) was highly significant ($t = 7.13$, $df = 21$, $p < .001$). In another experiment, a factorial manipulation of sex and reward magnitude, the difference between 8 males (mean 135.5) and 8 females (mean 191.2) was also significant ($F = 12.21$, $df = 1/12$, $p < .005$). Haddad et al (1969) have also reported sex differences in the same direction on these tests. The differences were significant for microcephalic rats and approached significance in normals.

Table 2
Corrected Problem-Total Intercorrelations of Errors in the Symmetrical and Rabinovitch-Rosvold Tests

Symmetrical Maze Tests			Rabinovitch-Rosvold Tests		
Problem	All 102 Rats	50 Normal Male Rats	Problem	All 39 Rats	18 Normal Male Rats
T-1	.17	.56***	1	.64***	.05
T-2	.50***	.41**	2	.84***	.72***
T-3	.41***	.61***	3	.58***	.31
T-4	.44***	.46***	4	.70***	.80***
T-5	.07	.16	5	.52***	.28
T-6	.48***	.48***	6	.72***	.67**
T-7	.55***	.27	7	.72***	.68**
T-8	.41***	.14	8	.62***	.36
T-9	.40***	–.01	9	.71***	.58*
T-10	.67***	.40**	10	.77***	.40
T-11	.66***	.26	11	.81***	.78***
T-12	.31**	.18	12	.24	–.25

* $p < .05$ ** $p < .01$ *** $p < .001$

Sensitivity to Hypothyroid Deficit

Of the various learning tasks employed in our studies of TCAP- and thiouracil-induced cretinism (Davenport, in press), the symmetrical maze most clearly and consistently revealed "retarded" performance by the drug-treated rats. This finding, obtained in postdrug tests conducted many weeks after the cretinoid animals were shifted to normal diets, was analogous to Eayrs's (1960) demonstration of apparently irreversible learning deficits in the Rabinovitch-Rosvold tests in neonatally thyroidectomized rats, both in terms of the early thyroid deficiency condition and the general types of learning task that revealed deficit.

Data from the two cretinism experiments reported by Davenport were combined to provide a comparison of 22 hypothyroid and 27 control rats on individual symmetrical maze problems (lower panel, Fig. 4). On each of the problems, there were fewer errors by the controls, and the differences were significant ($p < .05$, two-tailed) on eight of the problems (T-2 and T-6 through T-12). The main finding here, however, is that the superiority of the controls clearly increased as problem difficulty increased; the Group by Problem interaction was significant ($F = 4.36$, $df = 11/517$, $p < .01$). Thus, in detecting both sex differences and hypothyroidism deficits, the more difficult problems generally showed the greatest sensitivity.

"Maze-Bright" and "Maze-Dull" Rats

The nine "maze-bright" rats we tested showed somewhat better performance than eight "maze-dull" rats in terms of mean errors per problem on three visual problems (T-6, T-7, and T-8), but neither that difference (group means were 22.3 and 33.1) nor a smaller difference in the same direction (23.6 and 25.3) on three nonvisual problems (T-2, T-9, and T-10) was statistically significant.

Internal Consistency

Intercorrelations (Pearson rs) among the individual problems of the symmetrical maze series were computed from the error data of all 102 Holtzman rats we have tested and various subgroups. For comparison, interproblem correlations were also computed for the Rabinovitch-Rosvold tests we gave to 39 (18 male, 21 female) Holtzman rats, 16 of which were among the 102 tested in the present apparatus. With both maze series, the obtained intercorrelation patterns varied considerably with the selected subsamples on which they were based, since rs were attenuated by the restriction of score ranges in homogeneous groups of normal males and altered in various ways by the inclusion of female and hypothyroid Ss.

In general, however, nearly all the interproblem correlations for both mazes were positive and often significantly so ($p < .01$), regardless of sample selection. Exceptions to this statement occurred with Problem T-5 of the symmetrical series and Problem 12 of the Rabinovitch-Rosvold series, neither of which correlated significantly more than once with any other problem, even with favorable selections.

The Rabinovitch-Rosvold tests showed a higher degree of internal consistency than did the symmetrical maze problems when the data from all 39 and 102 Ss were used. The 55 intercorrelations among Problems 1-11 of the former test series ranged from .29 ($p < .08$) to .75 ($p < .001$), and 46 of them were above .41 ($p < .01$). The 55 rs for the 11 intercorrelating symmetrical problems ranged from –.09 to .72, with 30 rs significant beyond the .01 level (r of .25 or over). This comparison indicated that the first 11 Rabinovitch-Rosvold tests all tend to measure the same thing, whereas with the present apparatus, rather distinct clusters of intercorrelations emerged in a manner suggestive of a multiple-factor battery.

This interpretation makes some intuitive sense when one examines the error data and maze patterns of the two problem sets. The older problems are more homogeneous in difficulty and tend to have a common *umweg* theme. In contrast, the symmetrical problems differ widely in difficulty and vary from an unimpeded diagonal path (T-1) to patterns resembling complex multiple-unit mazes (T-10). Thus, while the older set may approach an ideal of internal consistency for single-purpose tests, the present set may be tapping a wider range of abilities. The lower internal consistency of the symmetrical problems does not necessarily represent lower reliability of a type that limits validity; indeed, it can be argued that the apparent variety of "things measured" by the symmetrical tests provides a more extensive sampling of learning abilities and increases the chances of detecting group differences in at least some of those abilities.

The extent to which error scores on each of the individual problems correlated with total errors over the remaining problems is shown in Table 2 for both apparatuses. These corrected problem-total intercorrelations are presented for all Ss and for more homogeneous samples of normal male rats in each case. These data serve to emphasize certain points indicated by the interproblem correlations and to illustrate the influence of sample selection. In emphasizing the internal consistency of the first 11 Rabinovitch-Rosvold tests, the problem-total rs were occasionally high enough (e.g., Problem 2, uncorrelated r of .87) to raise the question of redundancy. The sample comparisons in Table 2 reflect some degree of attenuation of r values by restrictions of variability in the normal male groups and, particularly in the case of the symmetrical maze, indicate the extent to which given problem-total correlations were affected by the inclusion of poorer-learning groups. The sizable differences between the two columns of rs for the latter half of the symmetrical series were largely predictable from the sex differences and hypothyroid-control differences shown in Fig. 4.

The 16 rats that received testing in both apparatuses provided an insignificant correlation of .34 ($t = 1.35$) between the total error scores of the two problem sets. These Ss also received a retest on seven of the symmetrical problems after an intervening set of asymmetrical problems. The correlation between total errors on the retest and Rabinovitch-Rosvold error totals was .56 ($t = 2.52$, $p < .05$).

Test-Retest Correlations

Significant evidence of test-retest

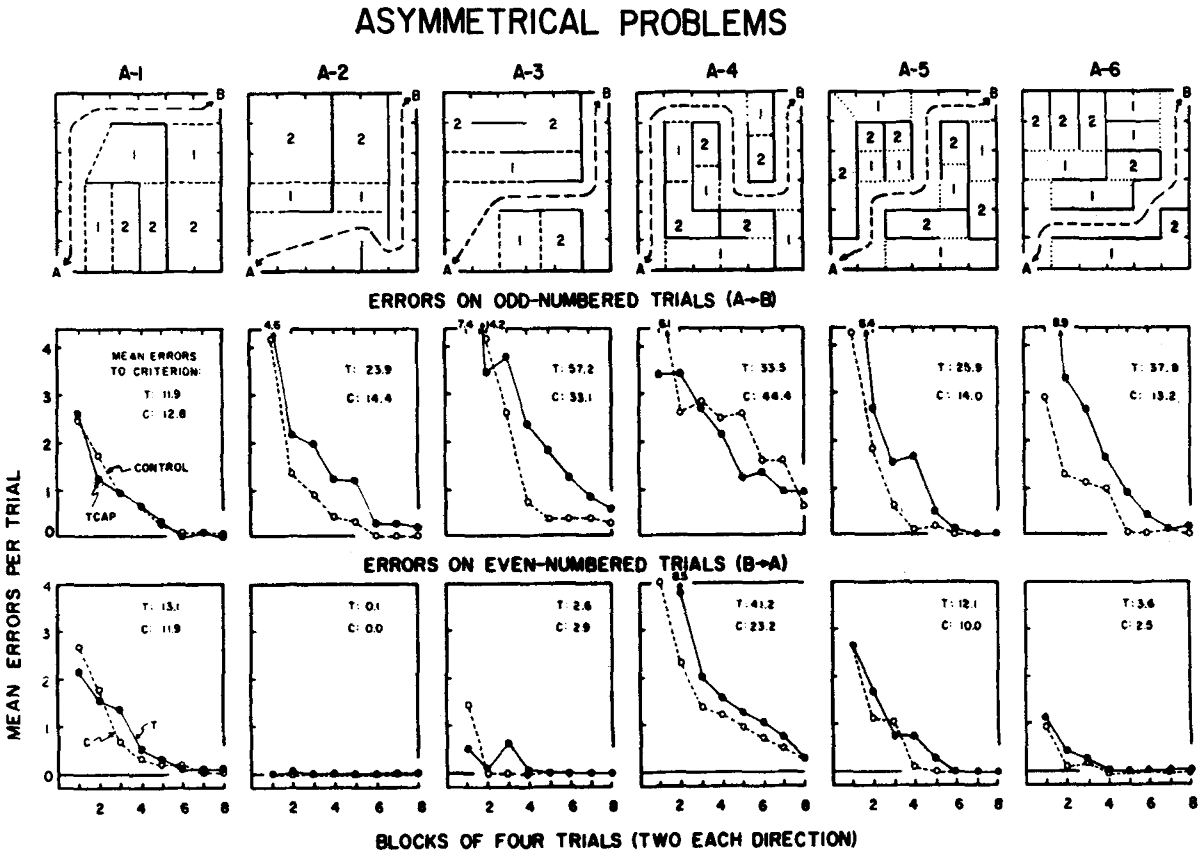

Fig. 5. The maze patterns of six asymmetrical problems (top row) and corresponding error curves of TCAP (T) and control (C) rats on A-to-B (middle row) and B-to-A (bottom row) subproblems. The group mean trials-to-criterion values represent total numbers of trials (in both directions) prior to reaching criterion on a given subproblem. Only the first 32 trials (16 in each direction) of each subproblem are shown.

reliability was obtained when the retest error totals of these 16 rats were correlated with test errors totaled over the same seven problems ($r = .66$, $p < .01$). The 30 Group N males were retested with the standard procedures on all 12 symmetrical problems immediately after their initial series. These Ss showed a correlation of .59 ($p < .001$) between the test and retest error totals. Both of these test-retest correlations were subject to attenuation from restriction of score ranges, since the variability of total-error scores on the retest was well below that on the initial test series; for Group N, the means and standard deviations dropped from 350.5 ± 76.9 to 170.9 ± 44.7.

Rabinovitch and Rosvold (1951, p. 127) reported higher test-retest correlations (rho of .84 for 28 normal and cortical-lesioned rats, rho of .80 for 18 normals only) for their test series. The difference between the two mazes in test-retest correlation may be due in part to the fact that Rabinovitch and Rosvold's retest problems were new patterns consisting of mirror-images of the original test problems, whereas (inversion of symmetrical problems resulting in no change) our Ss merely relearned previously administered problems. With both memory of specific patterns and learning-to-learn operating to facilitate retest performance, the correlations for the symmetrical maze may have been more attenuated by curtailed variability than were those for the Rabinovitch-Rosvold tests. Future refinements of the symmetrical problem series should include construction of an alternate form to circumvent this attenuation problem.

ASYMMETRICAL PROBLEMS

Figure 5 presents the maze patterns of six asymmetrical problems we have administered in the apparatus and a comparison of error curves for eight TCAP-treated and eight normal rats. These were the same 16 Ss that had previously been tested on the Rabinovitch-Rosvold and standard symmetrical problems. Problems A-1, A-2, and A-3 have the same barrier positions as Rabinovitch and Rosvold's Problems 3, 6, and 11, respectively. Performance on odd-numbered trials is shown separately from that on even-numbered trials, since, with a given pattern, S was confronted with a different problem in each direction.

The more difficult of these asymmetrical problems provided another striking example of rats' spatial-learning capacities and of the feasibility of the two-way shuttle procedure for automated complex learning apparatuses. All 16 rats learned all 12 subproblems (to a 2-of-3 criterion applied to each subproblem) within 50 total trials (25 in each direction). Even though the Ss had to learn two problems concurrently within a session, the overall difficulty of these asymmetrical problems was not much greater than that of the symmetrical problems (compare Figs. 3 and 5). Total errors over these asymmetrical problems correlated .59 ($p < .02$) with total errors on the preceding symmetrical problems.

With the exception of Subproblem A-4 (A-to-B), the differences between TCAP and control rats were similar to those displayed by the same rats on the symmetrical problems in that the superiority of the controls tended to increase with difficulty level. There was a suggestion, however, that asymmetrical problems in which one of the two subproblems is extremely easy (such as the

B-to-A subproblems of A-2, A-3, and A-6) may be more sensitive to hypothyroid deficit (note the corresponding A-to-B subproblems) than to difficult symmetrical problems.

MANUAL USE OF THE APPARATUS

Essentially the same procedures we have described for this automated apparatus can be carried out manually, with most of the advantages over older closed-field test methods preserved and at a considerable saving of equipment (automatic doors, photocells, programming modules, and closed-circuit television). With manually operated guillotine doors and electrically operated pellet dispensers, an E could administer trials and record errors from a single (visually shielded) position near the apparatus without handling Ss between trials. Although we have no experience to report with such an arrangement, it would seem to be nearly equal to our automated version in convenience, accuracy of recording errors, E influences, and applicability to species that are difficult to handle between trials. Except for the possibility that the low-level noise of the door motors may provide facilitative directional cues to Ss in the automated setting, there seems to be no good reason to expect any important differences between the automated and manual versions of the apparatus in the data obtained.

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A runway for the cockroach[1]

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A runway and training procedure that minimizes handling is described. Acquisition and extinction trials are presented to illustrate the technique.

Instrumental learning in cockroaches has been studied under escape-avoidance conditions (Longo, 1964), but no suitable food-reward procedure yet has been described in the literature, although it would be useful to have such a procedure for purposes of phyletic comparison.

Two problems have been encountered in our attempt to develop a food-reward procedure. One is that the appetite of the cockroach is not large enough. Minute quantities of food and water are sufficient to maintain the animals in a healthy, active state. The common roaches, *Periplaneta americana* and *P. orientalis*, have lived as long as 2 months without any food and water in my laboratory. The solution to this problem is to use a highly preferred food, such as canned crushed-and-sweetened pineapple. A second problem is that cockroaches, like fishes (Potts & Bitterman, 1968), are disturbed by handling. In earlier experiments, I attempted to minimize this difficulty by cementing a loop of nylon thread to the thorax of the animal and carrying it by the loop, but roaches are reluctant to enter a

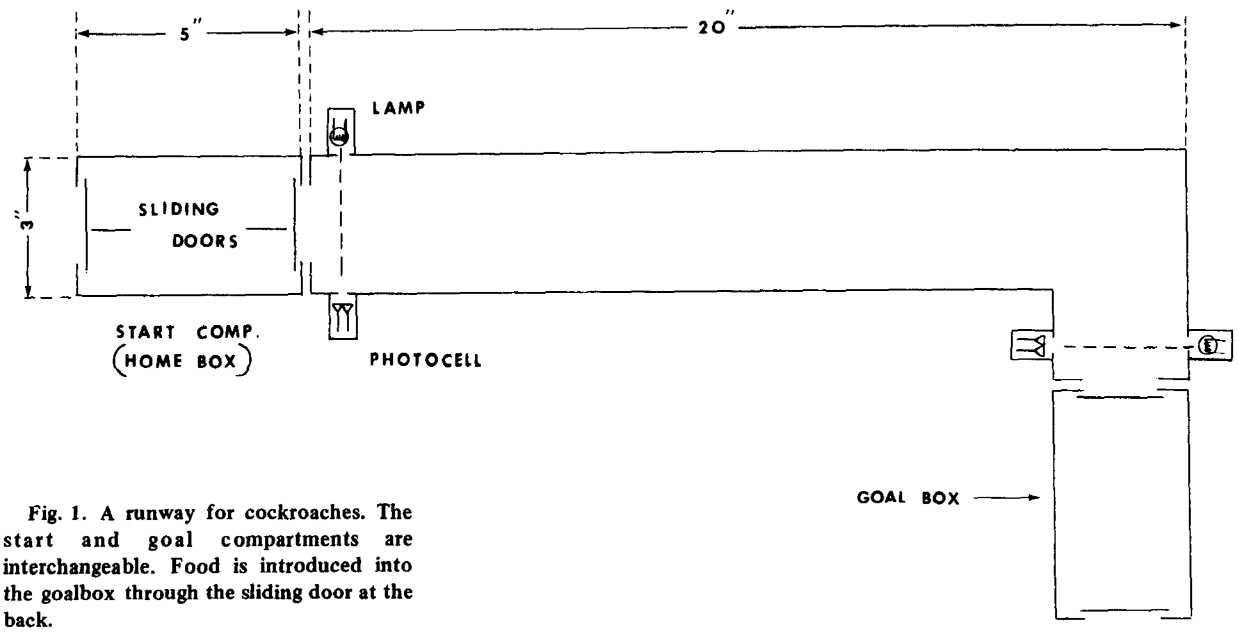

Fig. 1. A runway for cockroaches. The start and goal compartments are interchangeable. Food is introduced into the goalbox through the sliding door at the back.